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WEIGHT AND WEIGHTLESSNESS

Weight is simply the force of gravity (do you remember the formula $F_g = mg$?).

We are not normally aware of this force – what we are actually aware of is the normal reaction force that acts on us when we are in contact with, say, the floor or the seat on which we sit. Usually, this normal reaction force is equal to our weight (giving a net force of zero, which is why you do not accelerate while sitting on a chair). There are situations, however, when the normal reaction force is not equal to the weight. Such as?

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QUESTION 43
A physicist of mass 60 kg is patiently standing in an elevator. Determine the magnitude of the normal reaction force that acts on the physicist when the elevator is:

a. Stationary.

b. Moving upwards with a constant speed of 2 m/s.

c. Accelerating upwards at 2 m/s^2.

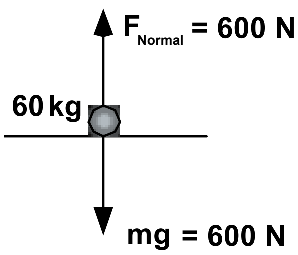
d. Accelerating downwards at 2 m/s^2.

Remember that, in each case, the reaction force on the violinist is her *apparent* weight.

Solution

a. The key fact here is not that the velocity is zero, but rather that the acceleration is zero presumably, the elevator is remaining stationary). This implies that $F_{net} = 0$, which in turn implies that the magnitude of the normal reaction force must be equal to the weight.

Now, the weight, mg, is 600 N and therefore the normal reaction force is also 600 N. Since force is a vector, we must include direction in our answer. So, normal reaction force = 600 N up.



b. As in part (a), the velocity is constant, so a = 0. Thus, again, the normal reaction force is 600 N up.

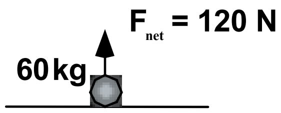
c. Since there is now an acceleration (specifically, a = 2 m/s^2 up), we know that a net force must be acting on the violinist. Finding this is easy:

$$F_{net} = ma$$

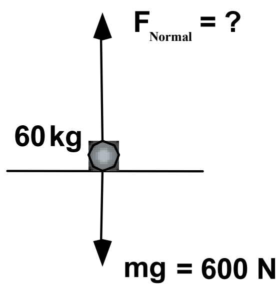
$$F_{net} = 60 \times 2$$

$$F_{net} = 120\ N\ up$$

(Notice that the net force is up, for the formula $F_{net} = ma$ tells us that F_{net} is always in the same direction as the acceleration.)



The net force is responsible for the acceleration. The net force is the sum of two forces: The weight and the normal reaction force. These forces are shown in the next diagram. Notice that the vector representing the normal reaction force is drawn longer than the vector representing the weight force. The normal reaction force must be greater than the weight in order to give an upward net force.



In fact, the normal reaction force must be 120 N greater than the weight force. Since the weight is 600 N, the normal reaction force must be 720 N upwards.

Alternative Solution

Some of you will not particularly like the above method. For those stricken with a love for algebra, try this:

First, just as we did above, use $F_{net} = ma$ to find the net force. Then note that the net force is the sum of all forces (two forces in this case) that act on the object.

$F_{net} = mg + F_{Normal}$

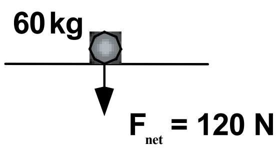
$+120 = (60)(-10) + F_{Normal}$ (Note our sign convention: up = +, down = -)

$+120 = -600 + F_{Normal}$

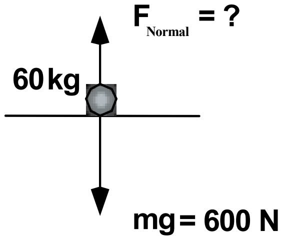
$F_{Normal} = +720$

Since + = up, our answer is 720 N up.

d. Now a = 2 m/s² down. We now find that $F_{net} = 120\,N\;down$.



In order to produce a net force that is directed downwards, the normal reaction force must be less than the weight.



Specifically, the normal reaction force must be 120 N less than the weight, giving us an answer of 480 N up.

Alternative Solution

$F_{net} = mg + F_{Normal}$

$-120 = (60)(-10) + F_{Normal}$

$-120 = -600 + F_{Normal}$

$F_{Normal} = +480$

$F_{Normal} = 480\,N\;up$

QUESTION 44 (3 marks)
A 79.0 kg person rides in a lift. Firstly, the lift accelerated upwards at 1.26 m/s^2 before then travelling at constant speed of 3.78 m/s to reach the 50th floor where it came to rest at 1.89 m/s^2.

a. Calculate the apparent weight of the person in the first part of the journey. (1 mark)

b. Calculate the apparent weight of the person while at constant speed. (1 mark)

c. Calculate the apparent weight of the person in the last part of the journey. (1 mark)

MOMENTUM AND IMPULSE

Momentum, $p = mv$, is a *vector quantity* (because it is the product of a vector, v, and a scalar, m). The direction of the momentum vector is the same as the direction of the velocity vector.

Momentum is terribly interesting because it is conserved – see below.

Consider the equation, $F_{net} = ma$. Since, $a = \frac{\Delta v}{\Delta t}$, we can rewrite $F_{net} = ma$ as:

$$F_{net} = m\frac{\Delta v}{\Delta t}$$

We can now transpose the equation thus: $F_{net}\Delta t = m\Delta v$.

The quantity $F_{net}\Delta t$ is known as the *impulse* (Unit: Newton second, N s). Impulse is simply force multiplied by the time over which the force acts. Impulse is a vector quantity – it has the same direction as the force.

The quantity $m\Delta v$ is the *change in momentum*, i.e. $\Delta p = m\Delta v$.

Δp (the change in momentum) has the same direction as Δv (the change in velocity).

The equation $F_{net}\Delta t = m\Delta v$ tells us that **impulse = change in momentum**.

It should be clear that an impulse will indeed cause a change in momentum: If a force acts over any period of time, it will cause an acceleration, i.e. a change in velocity. If an object's velocity changes, then it follows that its momentum also changes.

Note also that if we write the equation $F_{net} = m\frac{\Delta v}{\Delta t}$ thus: $F_{net} = \frac{m\Delta v}{\Delta t}$.

It follows that: $F_{net} = \frac{\Delta p}{\Delta t}$

Net force = Rate of change of momentum

This is simply Newton's 2nd Law.

As one would expect, Newton's 2nd Law implies that large forces will cause a rapid change in momentum.

QUESTION 45
A billiard ball of mass 0.10 kg approaches the cushion at 6.0 m/s and bounces off at 4.0 m/s in the opposite direction. The ball is in contact with the cushion for 0.05 s.

Find:

a. The force applied by the ball on the cushion.

b. The impulse given to the ball by the cushion.

Solution

We begin by choosing a suitable definition of directions, say:

Towards cushion = positive   Away from cushion = negative

Thus, for the ball, u = +6.0 m/s and v = -4.0 m/s

a. By Newton's 3rd Law,

(Force applied by ball on cushion) = - (Force applied by cushion on ball)

i.e. $F_c = -F_b$

Calculating the force on the ball is easy:

$$F_b = \frac{\Delta p}{t} = \frac{m\Delta v}{t} = \frac{m(v-u)}{t}$$

$$F_b = \frac{0.10(-4.0 - +6.0)}{0.05}$$

$$F_b = -20N$$

But $F_c = -F_b = -(-20)$

So $F_c = +20N$

$F_c = 20N$ towards the cushion

b. Impulse $= \Delta p$
$= m\Delta v$
$= m(v-u)$
$= 0.10(-4.0 - +6.0)$
$= 1.0Ns$